



Engineering, Operations & Technology
Phantom Works

Phantom

Non-Autoclave (Prepreg) Manufacturing Technology

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The Boeing Company

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Cytec Engineered Materials

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Manufacturing Technology**

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Introduction - Why? Addressing Technical Challenges to Enable Disruptive, Pervasive Use of Non-Autoclave Manufacturing

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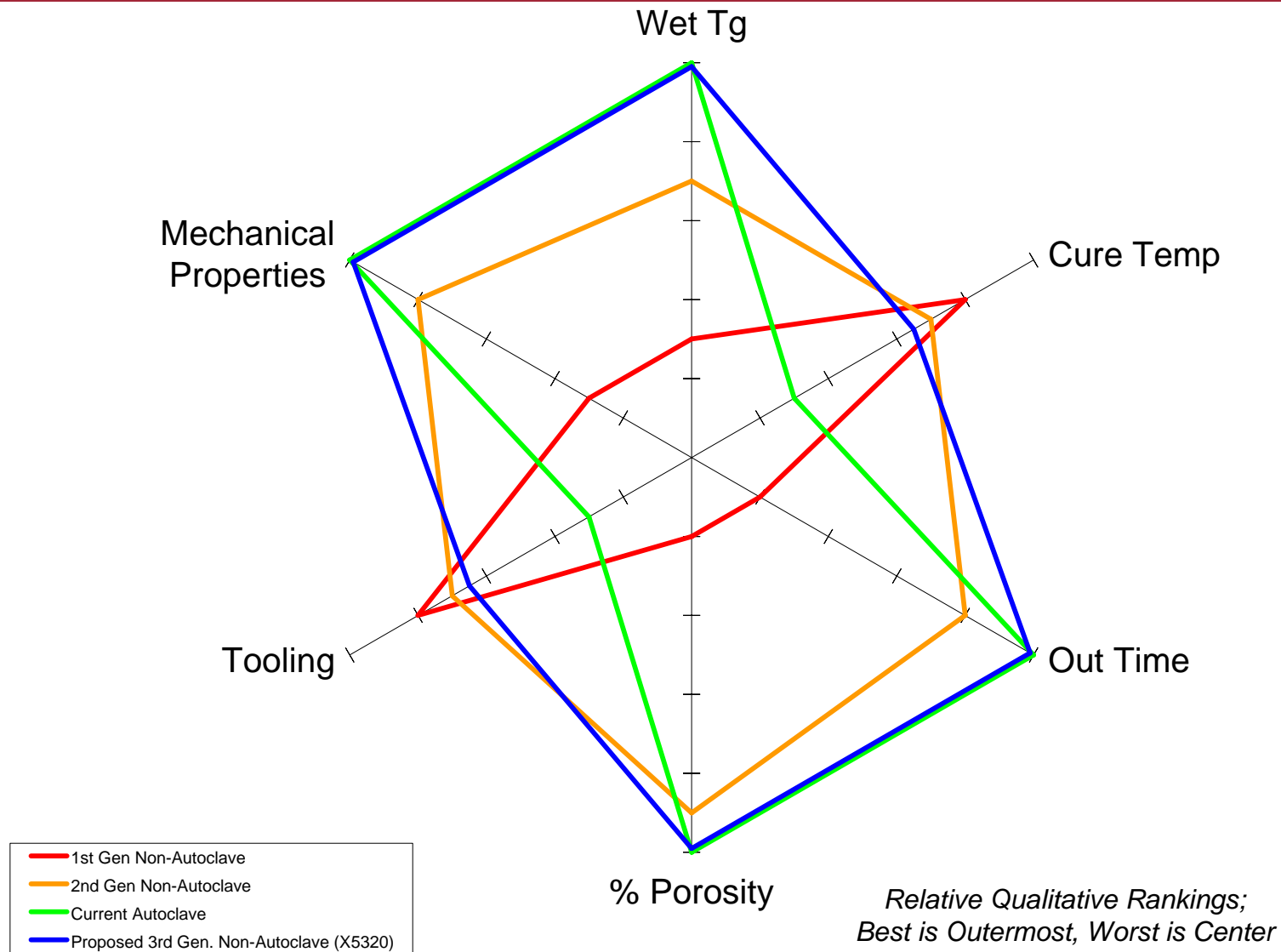
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- **Autoclave-Like Properties With an Initial Cure Temperature of 93°C with Vacuum Pressure Only and a Free Standing Post Cure @ 177°C**
- **Large, Void Free Components**
- **Material Family for Monolithic, Co-cured, Co-bonded Unitized and Sandwich Structures**
- **Structural Life >5,000 Hours**
- **Reduced Cost/Span Time Tooling Family for Use in 10-25 Units**
- **Processing and Tooling to Match Production**

Targets for Third Generation Vacuum-Bag-Only Prepreg Processing

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Program Approach

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Z, T, hats, honeycomb, syncore,
Thick, large, ramps, complex contour



Equipment studies – ovens, vacuum pumps

Freezer life

Processing variations – ramp rate,
Temperature, vacuum, debulk, damming, cure and post cure

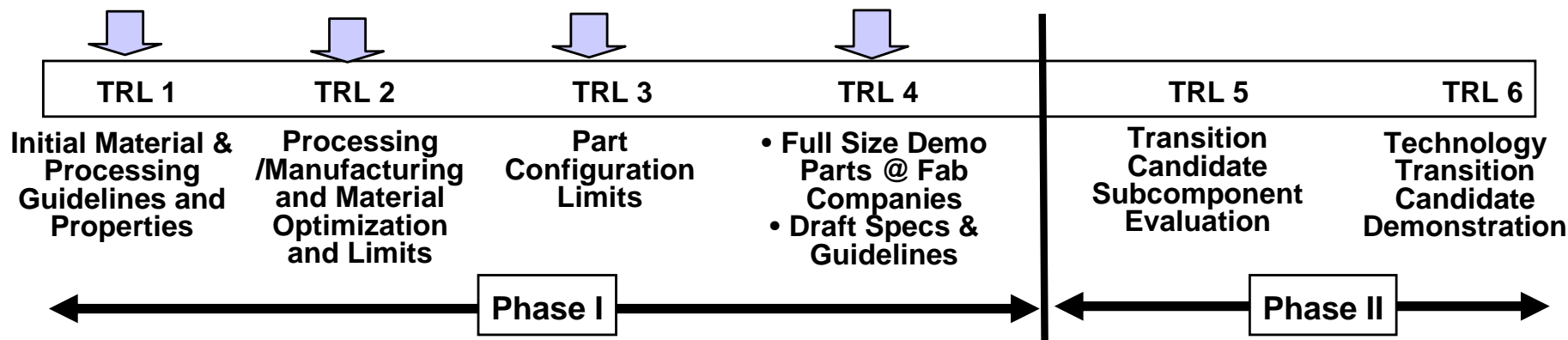
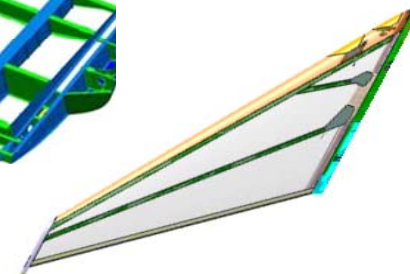
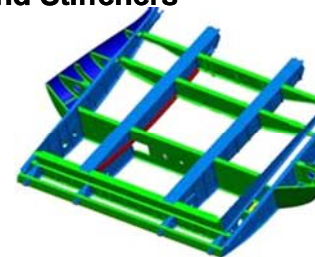
Cross-ply, quasi-isotropic panels

15 and 30 day out time discriminator panels

Rabbit panel

Composite Design Options

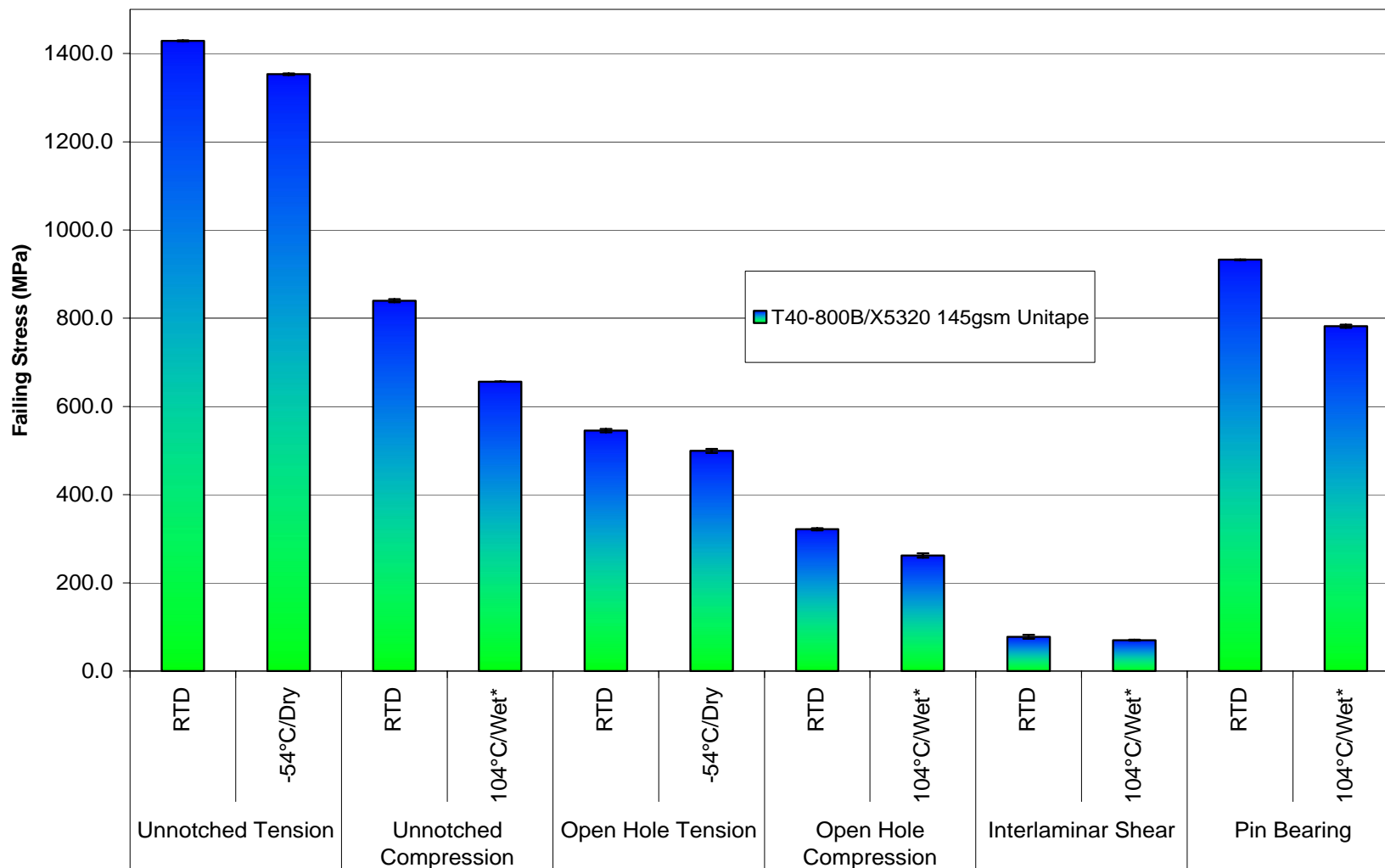
- Individual Monolithic Skins and Stiffeners (I's, C's and/or Z's) Secondly Attached
- Sandwich Skins and Stiffeners (I's, C's and/or Z's) Secondly Attached
- Cocured/Cobonded Hat Stiffened Skins and Stiffeners (I's, C's and/or Z's) Secondly Attached
- Unitized Skin and Stiffeners



Materials – Candidate C Properties for the Unidirectional Intermediate Modulus Fiber 145gsm Product Form

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*Moisturized at 88°C/82%RH to Equilibrium.

UNT, UNC – [(90₂,0₂)₂]_s

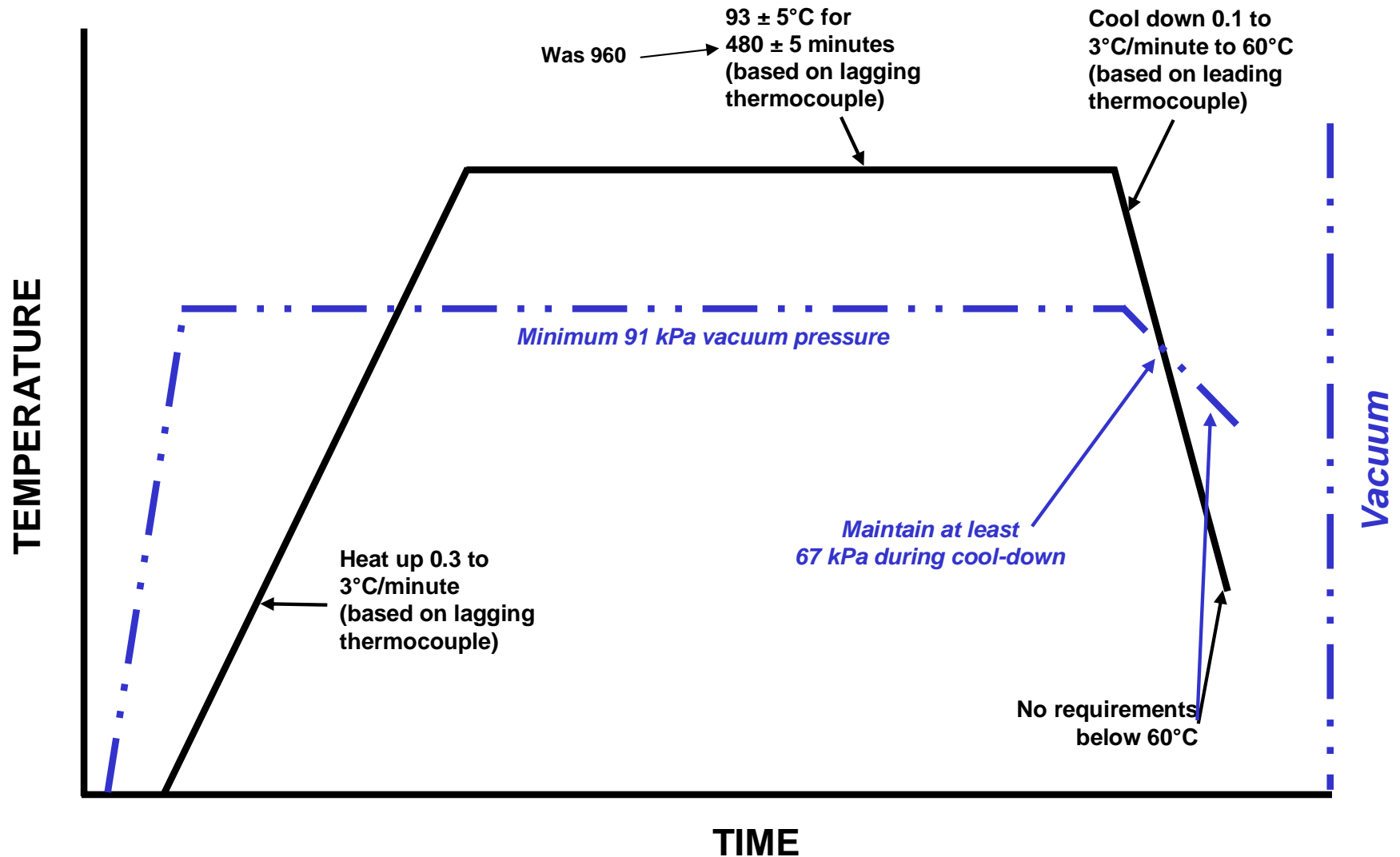
OHT, OHC, ILS, PB – [(+45₂,0₂,-45₂,90₂)₂]_s

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Typical Cure Cycle for X5320

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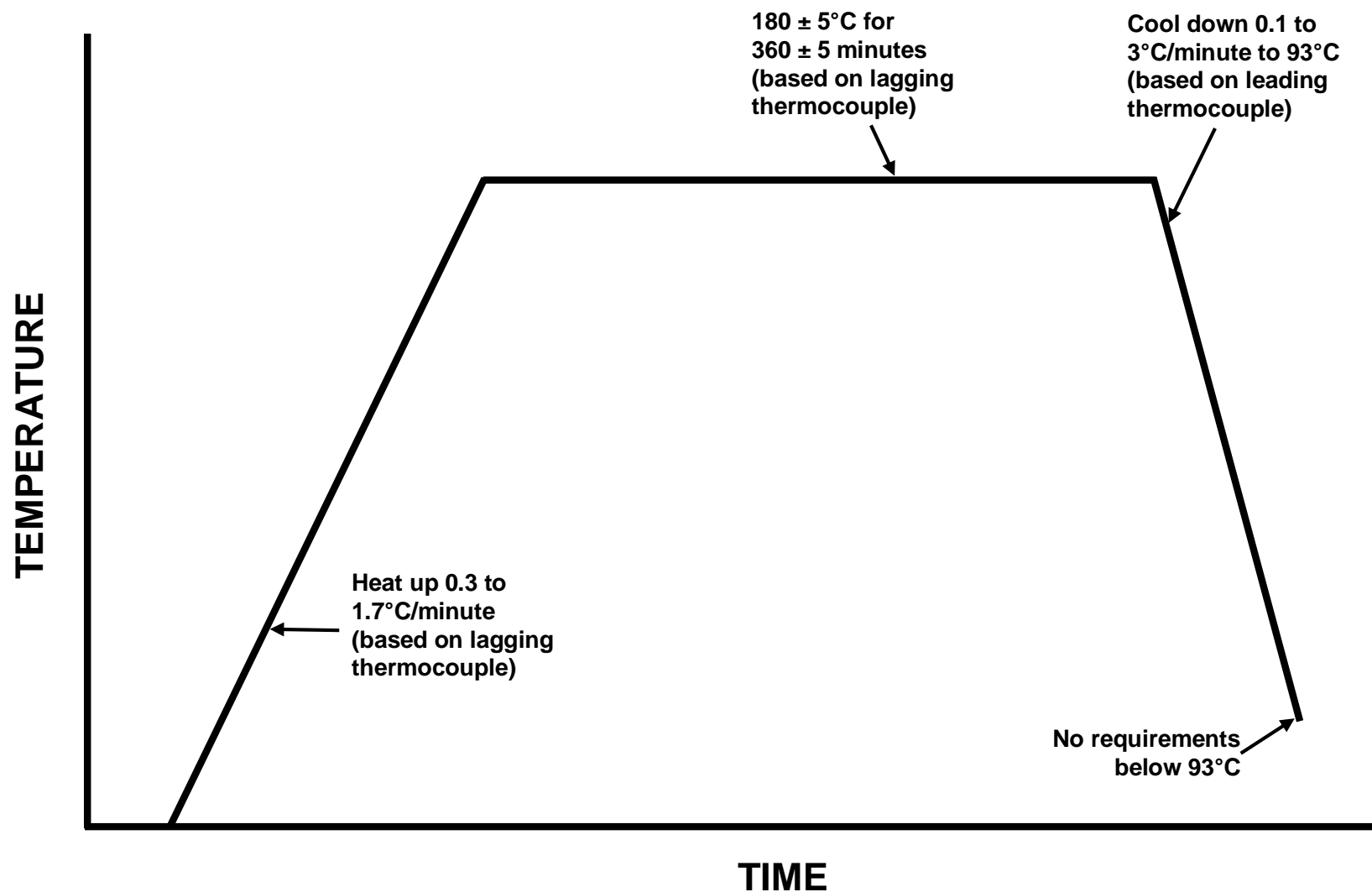
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Typical Freestanding Post-Cure Cycle for X5320

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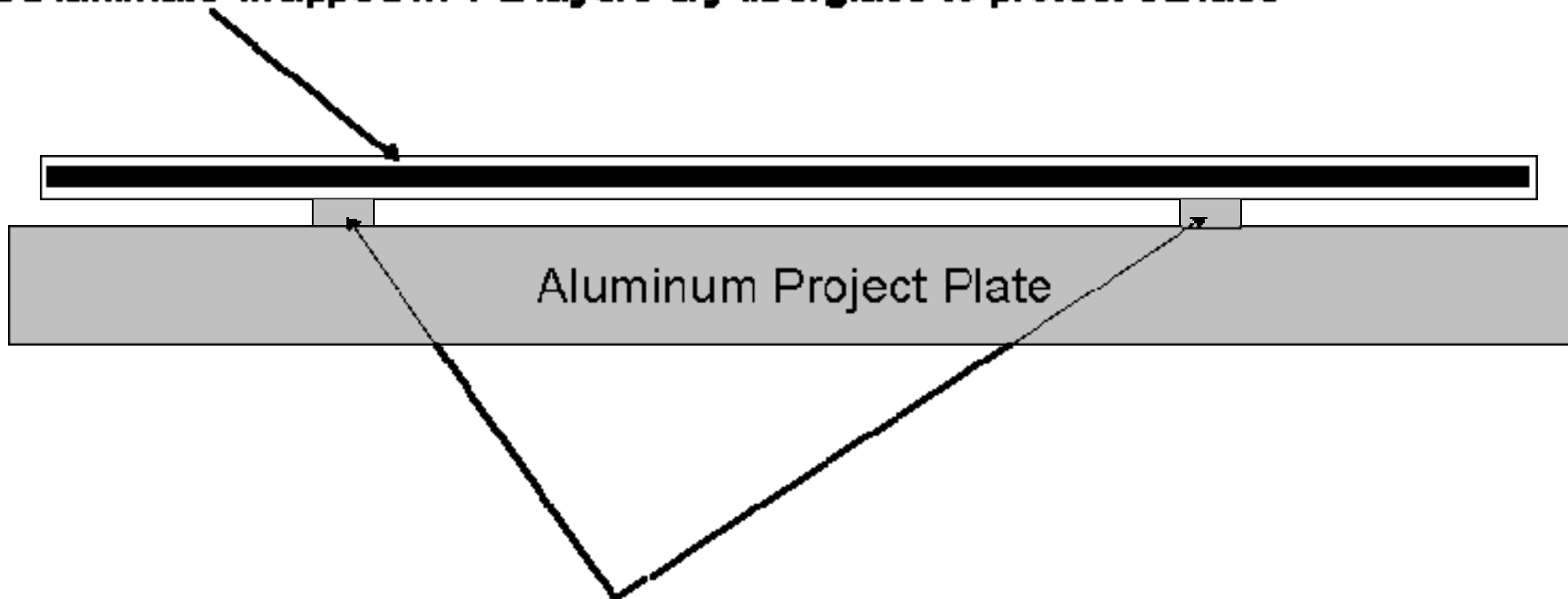


Cross Section of Boeing's Post-Cure Configuration for Processing Studies

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Cured laminate wrapped in 1-2 layers dry fiberglass to protect surface



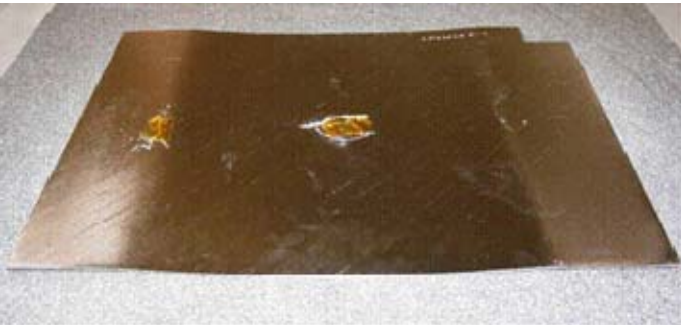
**2.5 cm (wide) x 1.3 cm (high) aluminum support beams;
spaced approximately 46 cm apart, run most of the width of panel.**

Schematic only, not to scale.

X5320 Candidate B Quasi-Isotropic Panel after Post Cure

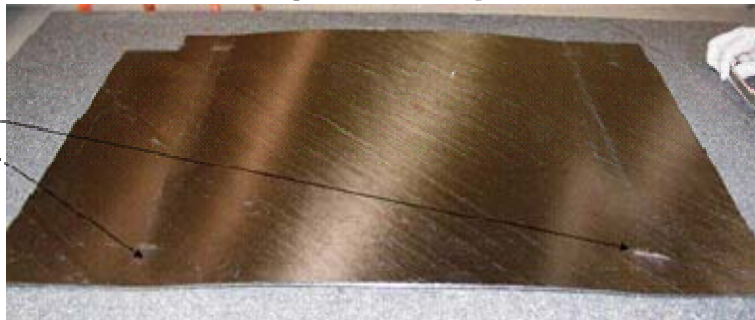
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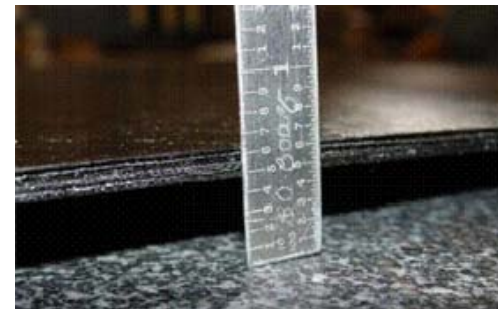


(a) X5320 Candidate B Quasi-isotropic Panel -1 Top

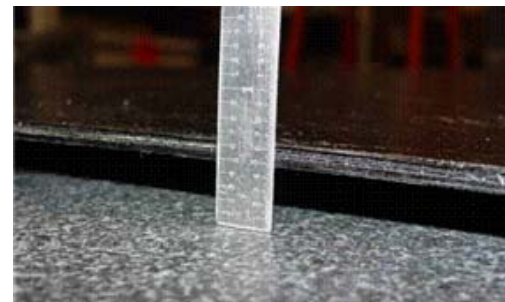
Mark-off from
aluminum supports
and dry fiberglass
(laminate wrap).



(b) X5320 Candidate B Quasi-isotropic Panel -1 Bottom



(c) X5320 Candidate B Quasi-isotropic Panel 1, Bottom-up, Middle of Side 1

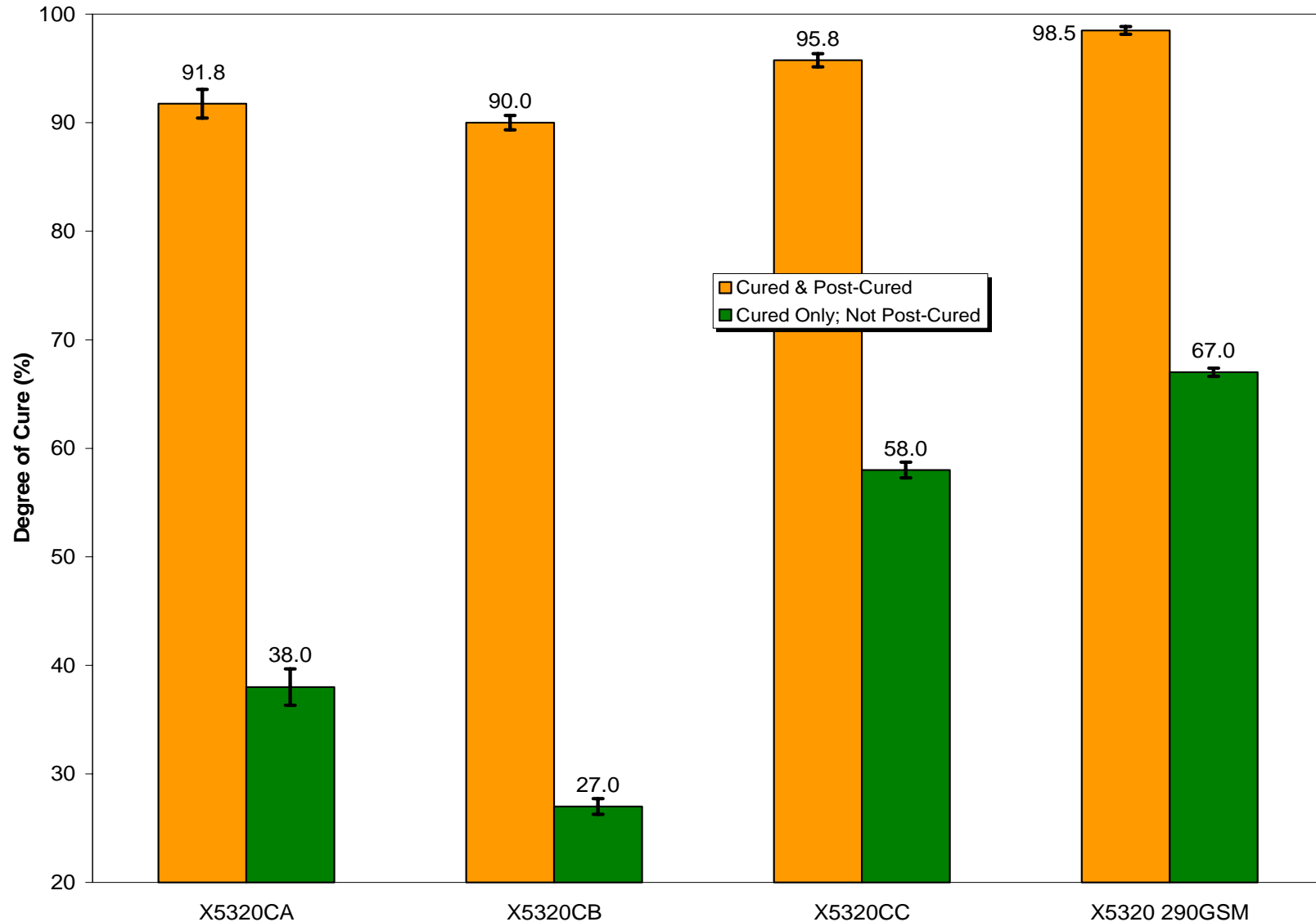


(d) X5320 Candidate B Quasi-isotropic Panel -1, Bottom-up, Middle of Side 2

X5320 Degree of Cure (All Cures: 16-Hours)

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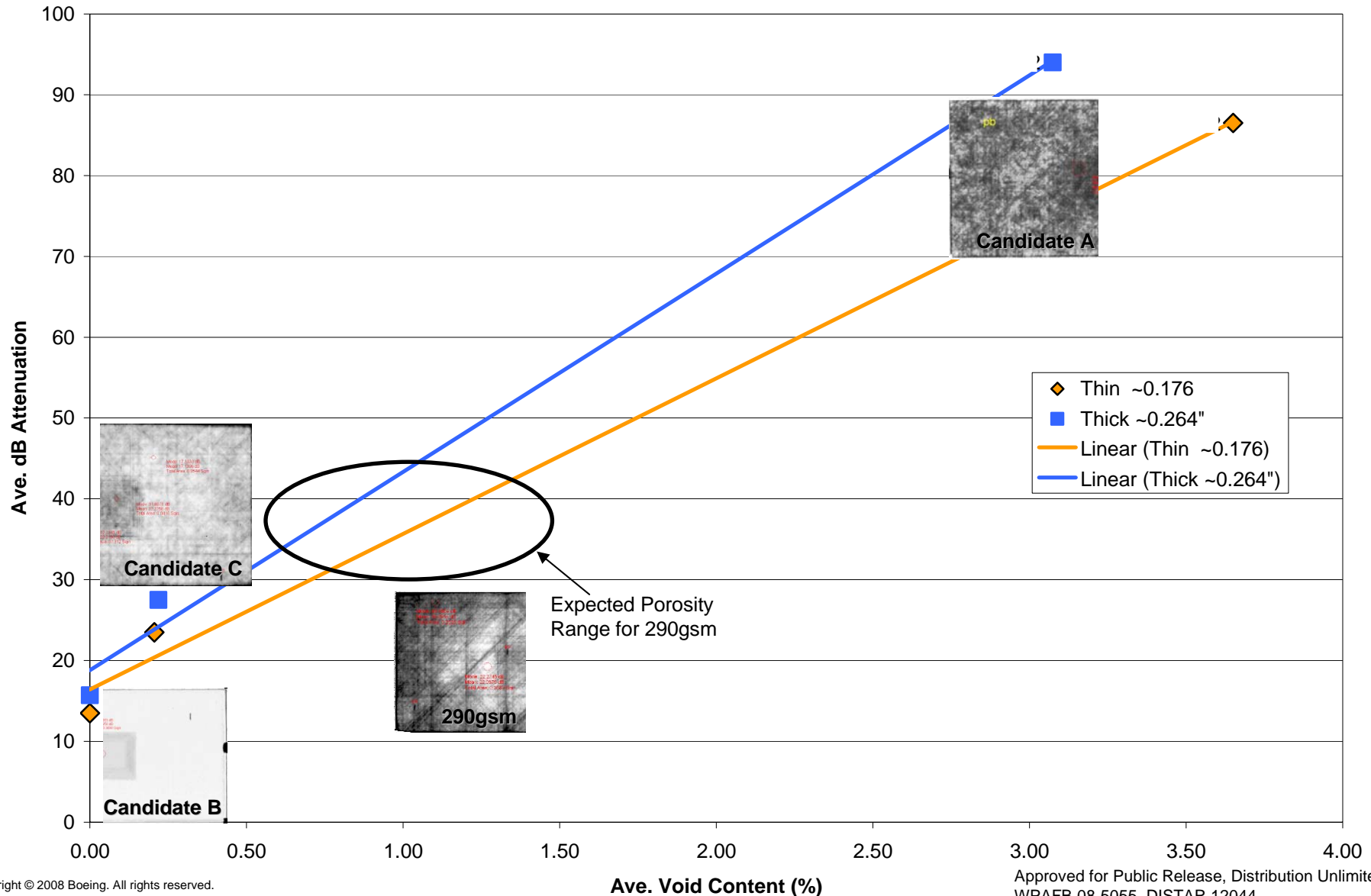
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X5320 30-Day Out-Time Comparison Attenuation versus Void Content

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Tooling Concepts and Replication

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Selected tooling used for fabrication will be demonstrated to show acceptable repeated use for 10-25 units. Thermal cycling will include temperatures greater than the material processing temperatures (chosen to account for variability and still show robustness).



Brake Formed Polycarbonate



Hybrid Concept with
Surface Master™ 905M ECS

New Tooling Concept for Cure Tools

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Convective Heat Transfer is Function of Gas Velocity and Density.....

Heat Transfer - Convection
↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓

Bagging Film →

Breather →

Separator Film →

Part →

Insulator Tool

Total Heat Transfer

Heat Transfer – Thermal Diffusivity

Minimal Heat Transfer – Thermal Diffusivity

Conductive Heat Transfer is Function of Material Thermal Conductivity.....






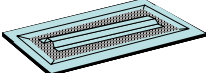
Total Heat Transfer

↑
Heat Transfer - Convection

Summary of Carbon Material Forms and Processing Evaluations

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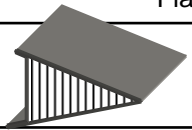
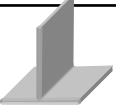
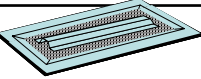

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Test Part Configuration	X5320CC (T40-800 145gsm) 2 Apr 08	X5320 290GSM (T40-800 290gsm) 30 May 08	X5320PPT (T40-800 145gsm) 10 Jun 08	X5320PPC (T650-35 3k 8HS) 26 Jun 08	X5320FST (T40-800 290gsm) 22 Jul 08	X5320FSC (T650-35 3k 8HS) 22 Jul 08	X5320PPHM (HR40 145gsm) 15 Oct 08
 Flat (Mechanical)	X						?
 Out-time Discriminator	X	X		X			
 Rabbit	X	X					
 C						X	
 Angle						X	
 Hats (Co-cure and Co-bond)				X			
Freezer Life and Processing (Vacuum, Heat-up, etc.)			X				
Microcracking							X
Large Contour Section, 18 ft. Distance Study			X	X	X		

Summary of Other Materials and Processing Evaluations

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Test Part Configuration	FM 209M (Epoxy Film Adhesive) 26 Jun 08	FM 300-2K (Epoxy Film Adhesive) 5 Sep 08	FM 490A (Epoxy Foaming Adhesive) 12 Sep 08	X5320PPQ (Quartz 4581 8HS) 1 Aug 08	FM 381 (Epoxy Syntactic Core) 12 Sep 08
 Flat (Mechanical)				X	
 Honeycomb	X	X	X	X	
 T	X				
 Hats (Co-cure and Co-bond)	X	X			
 Syntactic					X

Feature Dissection

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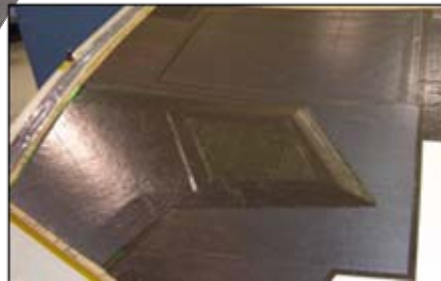
Part(s) of representative scale will be used to verify that representative key features can be acceptably produced with the materials, processes, and tools of this program via:

- Dissection and photomicrographic evaluation
- Limited static testing of features, and
- Engineering evaluation of fatigue on critical details

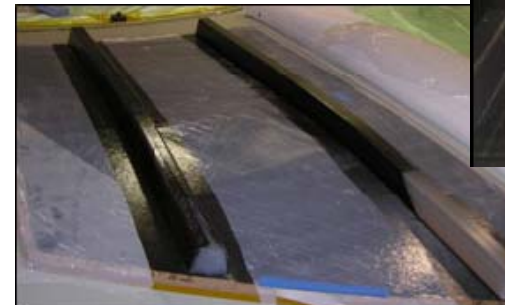
The 20 month demonstration article was fabricated by Boeing. Additional articles will be fabricated by subcontracted fabricators.



3 ft x 5 ft Stiffened Skin



Rabbet Detail



Hats and Blades



More Information

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- **Non-Autoclave (Prepreg) Manufacturing Technology -**
<http://www.darpa.mil/dso/thrusts/materials/novelmat/disman/index.htm>
- **In addition, we have been surveying the industry to evaluate priorities in non-autoclave manufacturing technology and with regard to industry specifications for these materials, please feel welcome to contact the authors for more information or a survey.**
- **3' x 5' X5320 Co-Cured Stiffened Skin**
is on display in the US Air Force
AFRL/RX exhibit space (323)
until 4PM tomorrow.

